EQUIPMENT AND ADMINISTRATION OF THE HIGH-SCHOOL BOTANICAL LABORATORY

HAPPILY in all the schools of the state, the laboratory sciences are now recognized as a part of every course of study. You will recall that only four or five years ago we were engaged in apologies and arguments for maintaining these studies as laboratory studies. The past four years have seen wonderful progress in laboratory equipment; and now we can turn our attention from arguments for being, to the work of determining the best in subject-matter and in method. Our task is, therefore, unpretentious; but it is hoped that the details presented may not prove wearisome.

There are two reasons that give the speaker a measure of confidence in appearing before you in discussion of this topic. One is his desire to define with some precision the university requirement for admission botany; the other is his desire to offer a helpful criticism to some pernicious methods used in teaching botany, his knowledge of these methods having been gained by his inspections of more than a dozen of our diploma schools during the past few years, and from the papers presented by those taking the examination for admission to the university.

Before we can ascertain the proper equipment and management of the laboratory, we must revert to the aim of the study. Permit me, therefore, to repeat here, that, to my mind, the aim of a biological study is threefold:

1. To train the pupil to see.
2. To train in the use of descriptive language.
3. To enable the pupil by stimulating inductive reasoning to gain some notion of natural relations, including his own relations to nature's creatures and nature's laws, including, also, his relations to his fellow men.

While the first two aims are common to all laboratory science, and are secondary, the third is preëminently, though not solely, the function of biological study.

If, now, we have clearly in mind the aim of the study, accuracy of observation, of description, and the perception of natural laws, we may inquire what the subject-matter should be in order to fulfill this aim.

Obviously the matter used and the course pursued will depend very largely upon the kind of training received by the teacher. Whatever his training, his horizon for the perception of the relations in nature must be wide, and his vision clear; else he cannot direct the gaze of the pupil. To gain this breadth of view requires the lapse of time spent in training. How much time?

Not everyone is called; but I believe a minimum of two years of college training—a full course for four semesters—is necessary for all except the genius. The botanical department of the University of Michigan does not recommend those for teaching botany who have not had at least two years of botanical training in college. With such an amount of preparation there must be united a considerable degree of individual originality and progressiveness, in order that the teacher may adapt the work, meet new conditions, and feed his enthusiasm with new acquisitions.

We may assume that, in this part of the country, all teachers of botany in the high school have had their training along one or more of three lines of study. These are: (1) *description and identification of species;* (2) *microscopic and gross structure;* (3) *general botany*, including *structure, development, relationship, and physiology.*

Those whose training and teaching have been in the description and identification of plants are fast passing from the field of action, and with them their unscientific methods. Such teaching can never be scientific in the high school, and for that reason the university no longer recognizes it as preparatory work. The ability to make the classification of plants a science comes after a decade of study of structure, development, and physiology, not at the very beginning of botanical study. An enthusiastic "analyzer" of plants may arouse and maintain enthusiasm in purely descriptive botany. But something more than enthusiasm is needed; pupils, might, perhaps, be kept enthusiastic in building up dissected puzzles. The "analysis" of plants may sharpen the observation and bring accuracy in the use of language; but it should be distinctly understood that, though nature study may at certain times and places be used to teach language, and though in all studies the correct use of language should be cultivated and insisted upon, yet the function of a science study is to teach science, and not language. Let us remember the highest aim of biological study—to perceive, through the object studied, relations, principles, natural law. The mere naming of plants is well enough for recreation and for pupils in the lower grades. As a diversion, the

teacher in the high school may even spend a little time at it, taking the shortest cut possible to the finding of the label. But those teachers who practice it in the high school as a study have brought the whole science of botany into contempt. For the truth of this assertion, I appeal to the knowledge and experience of everyone who understands the meaning and function of science in the high-school curriculum.

The high-school study of botany must therefore be either that on *structure* or on *general botany*, including the elements of structure, development, relationship, and physiology. A book constructed on the plan of the study of structure is Boyer's *Biology;* on general botany, Spalding's and Bergen's elementary manuals. Is there an advantage of one of these plans over the other? I believe there is a decided advantage in the latter plan. The study of structural botany alone will teach accuracy of observation and description, but very often does not promote induction by which the pupil is led to contemplate the underlying principles, which are called natural laws. It teaches the *what* preëminently well; not so well the *why*. It very often stops with a study of *things*, *objects*, not penetrating the object to the principles which the object illustrates.

If, on the other hand, the study emerges from *structure* into development, *relationship*, and *physiology*, the things studied become the instruments, merely, for the perception of larger truth. Here not only the *what*, but the *how* and *why*, are forced upon the pupil, and the inert plant becomes dynamic, and, therefore, tenfold more interesting. But, as was said a little while ago, whether the course is structural or broader in its range, must depend upon the ability of the teacher. Whether one method or the other is pursued, the teacher should see to it that the work does not degenerate into a study of mere things.

We cannot discuss farther the matter for a course without considering the equipment of the laboratory. What is essential as a laboratory? A well-lighted room, with work-tables; dissecting microscopes, scalpels, or small-bladed knives, and small forceps; preserved material in alcohol or formalin. These, to my mind, are altogether indispensable for every laboratory. Other tools are helpful, and good lists can be found in any recent laboratory manual. In facilities and instruments not named, with the few given above, each school must decide for itself what it can afford and what the teacher can make use of. If simple experiments are to be used to teach plant activities, there will be needed, in addition to what may be borrowed from the chemical

laboratory, a small supply of dishes and glassware. If the teacher is prepared to instruct in microscopic anatomy. and the school can afford the expense, microscopes may be provided for a large part of the work. If it is proposed to teach the subject without much microscopical work, at least a few microscopes should be provided; for certain fundamental principles cannot be comprehended by the pupil without a fairly accurate notion of cell-structure.

After all that may be said on laboratory equipment, it should be remembered that the most important instrument in any laboratory is the brain of the teacher. It is folly to provide instruments which the teacher cannot use to advantage.

Aside from the laboratory property, each pupil should own, or be provided with, an individual equipment; this will be considered further on.

There are possibly some here who wish there might be given now an outline of a proper course of study, with a naming of material and experiments. As a teacher of botany, you doubtless possess Satchell's, Spalding's, and Bergen's elementary books, and MacDougall's *Plant Physiology*. If you cannot out of these books plan a course best suited to your abilities and to your school's resources, there is no help for you. "But," you say, "these manuals contain too much for a half year's study." Of course they do; but you must have originality enough to select what you can use to best advantage. These books give the proper method. They are not intended as fetters, but as aids. You should know how to select, to reject, and to substitute material of your own for the author's prescription. If, for instance, you are using a manual which calls for acorns, and you cannot find any acorns, do not think that the completeness or success of the course is lost for want of acorns; there is not any one thing there that may not be dropped out without greatly marring the work.

A poorly managed laboratory is often a school of instruction in the art of wasting time. Whether the high-school course be altogether structural botany, or whether it be structural and physiological, the students must be held to their tasks. The work must be hard, but not irksome, requiring mental concentration and not frivolous. In no other way can it be disciplinary. Better a hundredfold spend the time on language or history or mathematics than to become slovenly or frivolous on the thin pap of diluted science. The superintendent and the principal can help in this matter. They can see whether the pupils are wasting time, whether the study is only informational, instead

of promotive of mental effectiveness and disciplinary of the reasoning powers. This is not merely the old outcry against teachers; it is a suggestion to superintendents and principals to analyze pedagogically the work of the teacher in botany, often young and inexperienced, and to help make it effective and disciplinary, by suggestions from the pedagogical side.

Turning from school principal to the teacher, it may bear repetition to say that the efficient teacher will have a clear idea of the end to be attained by the pursuit of the study, and, what is more important and more rarely found, will know the steps to the end; more, even, than this — the teacher will, at any stage in the course, be able to criticise the steps taken as true or false with respect to the path he is traveling. Above all things, let him remember that he is studying plants, not merely to know plants, but, through them, to read the workings of nature.

In order to escape the charge of being an unpractical college theorist, I wish to offer here some facts obtained from teachers of botany in high schools in this state. I have asked several of these teachers, of whose fitness to teach there is no question, whether pupils in the ninth and tenth grades can be expected so to pursue the study of botany as to use it as a means for the perception of natural relations and principles, including their own relations in nature. Without exception these teachers have replied in the affirmative, and have, moreover, stated that this aim of the study is the surest means of keeping alive the interest and the reasoning of the pupils. To give a precise illustration of the adaptation of laboratory work to the pursuit of the three aims of botany in the high school — accuracy of observation, accuracy of description, and the perception of natural relations, I will introduce here a set of review questions furnished me by a successful high-school teacher in this state, of several years' experience, who has also had an unusually broad university training. These questions are not written for this occasion, but come to me just as they were given to the pupils:

QUESTIONS FOR REVIEW II [THE LEAF].

What is a leaf? What are the parts of a typical leaf? What two principal functions do leaves perform? Is either of these functions in operation at any particular time, or under particular conditions? Name these conditions. Name the principal classes (kinds) of leaves. What is meant by venation? Explain the structure of the leaf-blade (three sets of things)? With respect to their venation name four kinds of leaves. What is a com-

pound leaf? Name and explain the two principal kinds of compound leaves. How can you tell simple opposite leaves on a little green twig from a compound leaf of similar appearance? Tell all you can about movements of leaves. Name some (three) of the principal modifications leaves may undergo. Purpose? What organs may serve as leaves when these are rudimentary or absent? Do these become leaf-like? Why? Apply this to other plant organs. Why is the leaf a thin, expanded structure? Account for the color of the upper and under surfaces. What would happen to a plant if it were stripped of its leaves? Why? What special functions may some leaves perform? Give examples. How does the leaf prepare for its fall in the autumn? What kind of a scar does it leave? How do you explain the change of colors? In what respects does the fall of the compound leaf differ from that of the simple leaf? What changes take place (*i. e.*, are externally visible) in the leaves of a plant placed in a dark-room or cellar? Why? What is the position of the leaves of a plant placed in a window? What happens if the plant be turned so that its leaves face away from the window? Explain these phenomena.

Assume, now, that we are in the laboratory to start the work; what is to be done? Each pupil will have plant-material, instruments, and tools to work with. Every pupil will have notebook, drawing-paper, a specially hard drawing pencil with needle point, etc. Do not make the mistake of allowing pupils to work with insufficient tools; do not let them think that they can work for even a day without what you regard as necessary. Either loan them what they need or excuse them from the work. Now that you have started them in the work, direct them wisely, telling them what you must, helping them to discover what they can. Avoid the use of a laboratory guide which endeavors to tell everything. Observation must be marked by originality; the descriptions must be close, in good English and complete sentences; the drawing must be accurate, and each one full of meaning. The first requisite for drawing well is a hard, sharp pencil, a pencil with needle-point. Such a point cannot be made with a knife alone; each pupil should have a plate of pumice stone or a bit of emery paper. There are conventions in drawing, even in botanical study; and the teacher should instruct his pupils in them. It is useless to say: "Draw just as it looks to you." We do not and cannot draw as objects look; we use conventions. For instance: If one is drawing cell-structure, he needs to be told that all very thin cell-membranes are to be represented by a single line, while all thick membranes are to be operated by a space between two parallel lines. Many such matters of convention must be directly taught. After assisting hundreds of stu-

dents in learning to draw in the botanical laboratory, I have come to the conclusion that continuously very poor drawing on the part of pupils is the fault of the teacher. Not that all can be taught to draw excellently; but I have yet to meet the student who cannot learn to make drawings fairly well. The teacher must show the pupils exactly the points and lines that are faulty, instead of giving general criticisms. The difference between exact portrayal and general effect must be taught. Drawings should not be made in the notebook, but upon hard, tolerably smooth-surfaced drawing-paper. The notes should recite all that the pupil works out. The boy who records his first hour's work in three sentences should either be given more to do or should receive instruction in the art of narration. During the progress of the work the teacher will take special pains, by the use of question and suggestion, to concentrate the pupil's thought, and to direct his attention to natural principles which his study illustrates.

For the experimental study of the activities of plants, the teacher will receive much aid from MacDougall's *Plant Physiology* and from Bergen's *Botany*. Some of the experiments can be performed by all the pupils individually, and some must be performed by the teacher, the pupils being required to take notes on the preparation and on the results.

Wherever possible, the laboratory period should be equal to two recitation periods. An hour is too short for the most effectual work.

What shall be said upon the relation of the laboratory to the text-book work? Let us not forget that science study is the study of things and their activities, not of books. In so far as science becomes a book study, it loses its distinctive function as a part of the curriculum. The book, therefore, should be used, not to teach science, but to summarize and extend the ideas gained in the laboratory. If you use laboratory work merely to illustrate the teachings of the book, you are in a false position, as you will learn if you take the census of opinion of the best teachers. Laboratory work first; then the text-book to summarize and supplement. Therefore, more time should be given to laboratory work than to the study of the text-book, and all recitations should at every point be connected directly with the laboratory. It is not information, but mental power that is the desideratum. If the mind is well trained, the pupil can gain outside of school and after he has left school much more information than he could ever acquire inside.

The teacher may here be warned against being turned aside from the study of general principles by outside clamor for the teaching of "practical" things. The teacher can do much to quiet this demand by taking pains to show that the best way to learn details of agriculture and horticulture is to acquire the general principles first, then to classify the details under these principles. The school does not have the time to teach the thousands of these details, but it can train the pupil so as to make him capable of acquiring them for himself.

SUMMARY.

We may conclude with the following summary:

1. The aim of botanical study in the high school is threefold: to give keenness to observation; accuracy in the use of descriptive language; to cultivate inductive reasoning, by which the mind is led to the perception of natural laws, and the pupil may recognize his relations in nature.

2. The teacher is not fitted for his work unless he himself perceives these relations, and unless he knows the path by which to conduct others to the goal.

3. The plan of the course of study must depend upon the training and ability of the teacher. It may be structural botany from a biological point of view, or it may be structural, relational, and physiological. It cannot be merely an external study leading to "analysis."

4. For laboratory work there must be a well-lighted room, fitted with tables and tools. Dissecting microscopes and a few compound microscopes are necessities, but whether there is to be a full equipment with compound microscopes will depend upon the ability of the teacher to use them to advantage.

5. The backbone of the course should be laboratory work, and the textbook an appendix to this. The laboratory work must be hard, but not irksome, and especial care must be taken to see that the study performs its disciplinary function.

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